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STUDY OF THE ^{20}O(d,t) REACTION WITH THE TIARA-MUST2-VAMOS-EXOGAM SETUP

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The reaction ^{20}O(d,t) has been studied in inverse kinematics using a secondary radioactive beam produced with the SPIRAL facility at GANIL. Fragments, light charged particles and gamma rays were measured with the TIARA, MUST2, VAMOS and EXOGAM detectors and preliminary results are reported. The level scheme of ^{19}O is built and the spin and parity of one state is tentatively assigned using the one-neutron transfer angular distribution.

1. Introduction

Experimental evidence for the modification of the magic numbers far from stability is accumulating. Measurements of atomic masses [1] and in-beam fragmentation gamma-ray spectroscopy [2] around shell closures are providing convincing evidence in regions such as N=20. Otsuka *et al.* [3] proposed that this modification results from changes in the monopole tensor force between the $\pi d_{5/2}$ and $\nu d_{3/2}$ orbitals. The consequence is the rise of the $\nu d_{3/2}$ orbital in neutron-rich nuclei when protons are removed from the $d_{5/2}$ orbital. Transfer reactions are very useful to study the shell structure of a nucleus as they probe the single particle nature of the nucleus and thus allow us to infer the single particle energies and shell gaps. The development of the N=14 and N=16 shell gap across neon and oxygen isotopes has been studied using (d,t) and (d,p) transfer reactions in inverse kinematics at GANIL. With the ^{20}O(d,p) reaction, one expects to measure for the first time the single particle strengh in ^{21}O and measure the energy of the so-far unobserved $3/2^+$ state that carries the $0d_{3/2}$ strength [4]. Information concerning negative parity states in ^{19}O measured in (d,t) transfer reaction should also help to resolve uncertainties about the cross shell excitations in the N=16 region. Similar transfer reactions have been studied using a secondary ^{26}Ne beam. In this paper, only the preliminary results obtained for the ^{20}O(d,t) reaction will be reported.

2. Experiment

The secondary beam of ^{20}O was produced by the ISOL method using the SPIRAL facility at GANIL. A primary beam of ^{22}Ne was accelerated using the two CSS cyclotrons up to an energy of 77.5 A.MeV and stopped in a thick carbon target. The fragments were extracted from the target, ionized and accelerated in the CIME cyclotron to an energy of 11 A.MeV. The resulting beam was polluted to a level of 80% with ^{15}N despite the stripper used. The ^{20}O beam had a mean intensity of $\sim 10^4$ pps, and impinged a thin 0.6 mg/cm^2 CD_2 target.

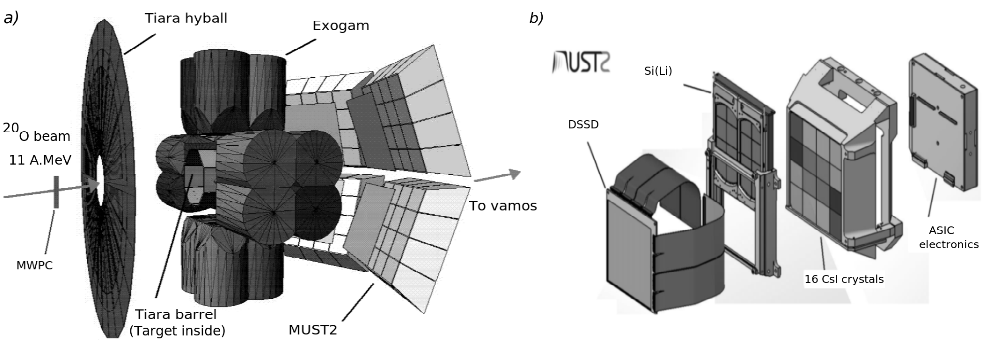

Fig. 1. (a) 3D view of the experimental set up around the target and (b) split view of a MUST2 telescope.

A complete set up was used to detect heavy fragments, light charged particles and gammas in coincidence [Fig. 1 a]. The TIARA [5] and MUST2 [6] silicon arrays were placed around the CD_2 target to detect the recoiling light charged particles. The TIARA Hyball annular detector was placed at backward angles, covering laboratory angles from 143 ° to 169 ° with respect to the beam axis. The TIARA Barrel surrounded the target covering laboratory angles from 36 ° to 143 ° and four MUST2 telescopes were placed in the forward direction, 18 cm from the target covering angles from 8 ° to 36 °. For γ-ray detection, four germanium clovers of the EXOGAM array [7] were mounted in a cross geometry around the target point, 50 mm away, yielding a total photopeak efficiency of 8% at 1 MeV. One multi-wire-proportional chamber (MWPC) [8] was placed 50 cm upstream from the target, yielding a measurement of the beam intensity and a start signal for the time-of-flight measurements. The heavy fragments were detected [Fig. 2 b] using the VAMOS spectrometer [9] placed at 0 °. VAMOS is a magnetic spectrometer made of two quadrupoles, one dipole and a detection system which includes two drift chambers, a ionization chamber and a plastic scintillator [Fig. 2 a]. The drift chambers measure the trajectory of the fragment and allows to reconstruct its rigidity and M/Q value using the time-of-flight measured between the MWPC and the plastic detector. The ionization chamber measures the energy loss of the particles, yielding the Z value of the fragment. MUST2 is a recoil particle detector made of six telescopes. Four of them were used during the experiment. Each telescope has three stages [Fig. 1 b]. The first stage is a double-sided-stripped detector (DSSD) whose thickness is 300 μm and that has 128 strips on both sides yielding a position resolution of 0.7 mm. The second stage is a padded Si(Li) detector (5 mm thick) that was not used during this experiment. The last stage is made of sixteen CsI crystals (4 cm thick). MUST2 has ASIC front-end electronics that insure a stable electronic response. If the light particle stops in the silicon strip detector, the identification is done using energy versus time-of-flight measurements [Fig. 3 a]. For particles punching through the first stage and stopping in the CsI crystals, the identification is done using the energy loss in the DSSD versus the residual energy in the CsI [Fig. 3 b].

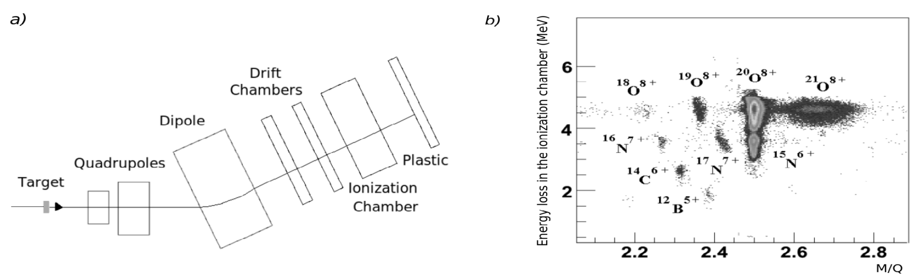

Fig. 2. (a) Schematic view of VAMOS and (b) A, Z and charge state identification of the heavy fragments using VAMOS.

3. Preliminary Results

Figure 4 a) shows the energy-angle scatter plot for the tritons in MUST2 in coincidence with a heavy ^{19}O fragment in VAMOS. The excitation energy of ^{19}O is reconstructed from the measured triton angle and energy using the two body kinematics. The resulting spectrum shows three peaks with an overall excitation energy resolution around 500 keV (FWHM) [Fig. 4 b]. Considering the spectroscopic information known for ^{19}O [10], the first peak located at -20 keV could correspond to the gs - 89 keV doublet. However, the γ-particle coincidences show no 89 keV γ-ray with the particles and the peak is therefore ascribed to a transfer to the ground state only. The second peak located at 1450 keV is unambiguously identified as the first $J^{\pi} = 1/2^{+}$ excited state of ^{19}O. Particles are in coincidence with γ-rays

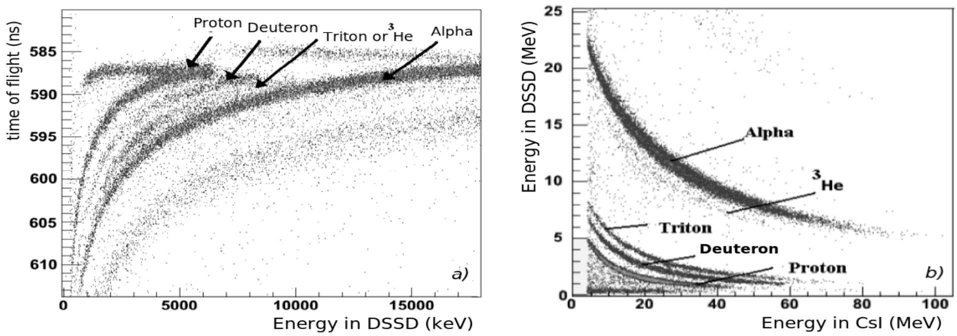

Fig. 3. Identification of the light particles with MUST2 by E-tof (a) and ΔE-E (b) measurements.

of 89 and 1375 keV confirming the known spectroscopy. There is one uncertainty concerning the third peak measured at 3232 keV. It could correspond to the $J^{\pi} = 5/2^{+}$ state located at 3153 keV or to the $1/2^{-}$ state located at 3231 keV. Particles are seen in coincidence with γ-rays of 89 keV, however the γ detection efficiency around 3 MeV becomes too low and the statistics are too limited to allow us to give a clear assignement. The angular distribution of the cross section for the transfer reaction to the 1.4 MeV excited state is plotted in Fig. 5 b). The angular range of MUST2 has been divided in 8 bins of 3.75° in order to have sufficient statistics for each bin. Error bars are stastistical only. Three DWBA calculations have been performed using the code TWOFNR [11] for different transfered angular momenta. The Daehnick [12] and the Becchetti-Greenleess [13] global optical potentials were used to calculate the deuteron and triton distorted waves, respectively. The different calculations have been arbitrary normalized to the fourth point of the experimental distribution. The L=1 and L=2 calculations are relatively flat over the covered angular range and do not reproduce the data. Only the L=0 calculation fits the data and particularly the first minimum around 14° in the center of mass frame, thus confirming the spin and parity $J^{\pi} = 1/2^{+}$ of the 1.4 MeV state. The angular distribution for the ground state and the 3.2 MeV excited state are too flat over the angular range covered by MUST2 to be able to separate a L=1 from a L=2 transfer. Including the data measured at larger angle in the TIARA Barrel should allow us to locate the position of the first minimum and thus differentiate the two contributions.

4. Conclusion

We have implemented and tested a high efficiency exclusive detection system to measure gamma, particle and fragment coincidences for direct reactions in inverse kinematics. Results obtained for ^{19}O are in good agreement with the known spectroscopy. However the analysis is still in progress. The study of the angular distri-

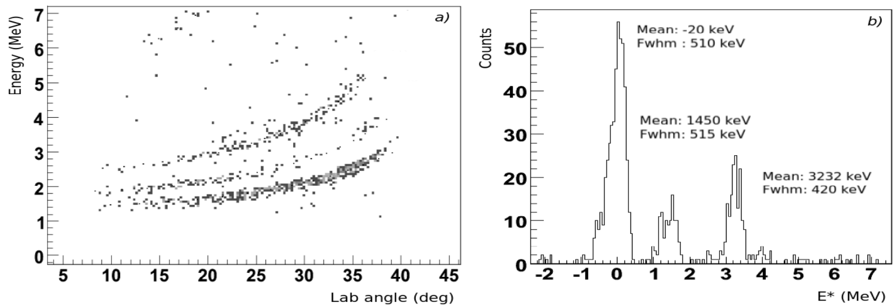

Fig. 4. (a) E-Θlab scatter-plot of the tritons from the ^{20}O(d,t) reaction at 11 A.MeV and, (b) reconstructed excitation energy spectrum of ^{19}O.

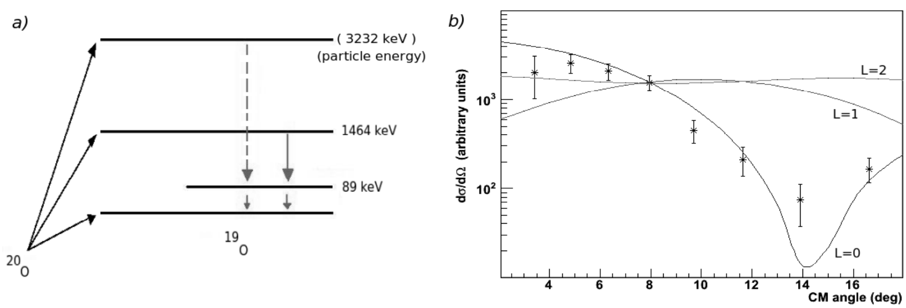

Fig. 5. (a) Level scheme of ^{19}O and, (b) angular distribution for the (d,t) transfer reaction to the 1.42 MeV excited state of ^{19}O. The solid lines are DWBA calculations for L=0, 1, 2.

butions using DWBA calculation must be completed in order to extract the spectroscopic factors. Finally, our results will be compared to shell-model calculations to probe the rigidity of the N=14 shell gap.

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